(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 576 791 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number : **93105404.3**

(51) Int. Cl.[5] : **H01L 21/00**

(22) Date of filing : **01.04.93**

(30) Priority : **16.04.92 US 870446**

(43) Date of publication of application :
05.01.94 Bulletin 94/01

(84) Designated Contracting States :
DE FR GB IT NL

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(54) Multi-zone illuminator with embedded process control sensors.

(57) A multi-zone illuminator for processing semiconductor wafers is described which comprises a plurality of source lamps and dummy lamps embedded in the reflector side of a lamp housing. The source lamps are arranged in a plurality of concentric circular zones. The illuminator also comprises plurality of light pipes for receiving multi-point temperature sensors to measure the semiconductor wafer temperature and its distribution uniformity. A gold-plated reflector plate is attached to the bottom side of the lamp housing for reflecting and directing optical energy toward the wafer surface. The distance between the reflector plate and the wafer and the lamps and the wafer may be adjusted with the use of a spacial elevator and adaptor assembly. The multi-zone illuminator of this invention allows uniform wafer heating during both transient and steady-state wafer heating cycles.

Other devices, systems and methods are also disclosed.

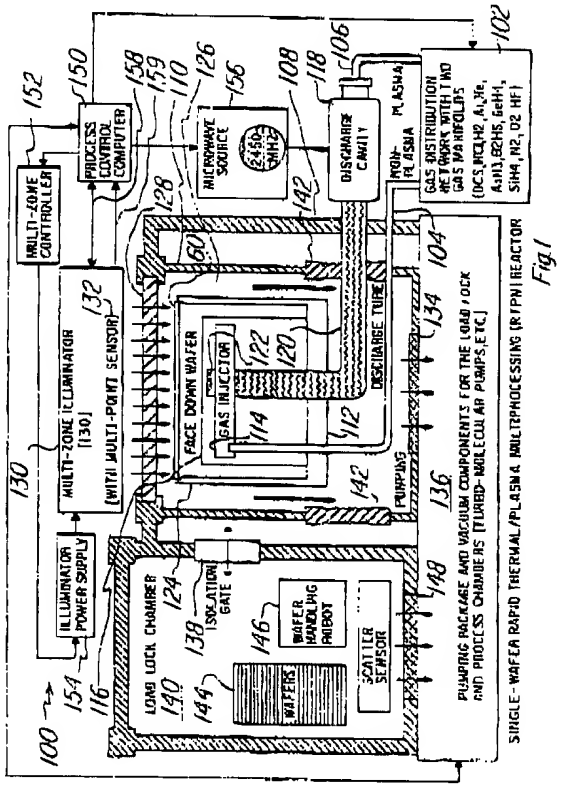


Fig.1

EP 0 576 791 A1

FIELD OF THE INVENTION

This invention generally relates to semiconductor device processing and more particularly to a multi-zone illuminator with embedded real-time process control sensors for uniform wafer processing in rapid thermal processing reactors.

BACKGROUND OF THE INVENTION

Without limiting the scope of the invention, its background is described in connection with single-wafer rapid thermal processing of semiconductors wafers, as an example.

Single-wafer rapid thermal processing (RTP) of semiconductors is a powerful and versatile technique for fabrication of very-large-scale-integrated (VLSI) and ultra-large-scale-integrated (ULSI) electronic devices. It combines low thermal mass photon-assisted rapid wafer heating with inert or reactive ambient semiconductor wafer processing. Both the wafer temperature and the process environment can be quickly changed and, as a result, each fabrication step can be independently optimized in order to improve the overall electrical performance of the fabricated devices.

Rapid thermal processing (RTP) of semiconductor wafers provides a capability for improved wafer-to-wafer process repeatability in a single-wafer lamp-heated thermal processing reactor. In prior art RTP systems, equipment manufacturers have spent significant design resources to provide uniform wafer heating during the steady-state heating, conditions. These prior art systems are designed with illuminators which provide single-zone or very limited asymmetrical multi-zone control capability. Thus, with an temperature distribution is affected. As a result, there are insufficient real-time adjustment and control capabilities to adjust or optimize wafer temperature uniformity during the steady-state and dynamic transient heat-up and cool-down cycles. As a result, the transient heat-up or cool-down process segments can produce slip dislocations as well as process non-uniformities. Various process parameters can influence and degrade the RTP uniformity. Prior art RTP systems are optimized to provide steady-state temperature uniformity at a fixed pressure. Thus a change in pressure or gas flow rates may also degrade the RTP uniformity.

SUMMARY OF THE INVENTION

Generally, and in one form of the invention, there is provided a multi-zone illuminator for processing semiconductor wafers comprising a plurality of source lamps; a plurality of zones arranged for generating optical energy for illuminating the wafer; optical means arranged to directing the optical energy; and a light interference elimination menas including at least one dummy lamp associated with each zone of source lamps for measuring light modulation depth.

An advantage of the invention is uniform wafer heating over a wide range of gas pressures and flow rates using the multi-zone configuration.

A further advantage of the invention is the use of adjustable reflector-to-wafer and lamp-to-wafer spacings.

A further advantage of the invention is providing the means for implementation of multi-point temperature sensors and light interference elimination components with minimum space and packaging complexity.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a schematic diagram of a single-wafer rapid thermal processing reactor for processing semiconductor devices using the present invention;

Figure 2 is a partially cut-away schematic diagram of a preferred embodiment of the present invention in association with the processing chamber of Figure 1;

Figure 3 shows a simplified view of a preferred embodiment of the multi-zone illuminator of the present invention;

Figure 4 is a schematic diagram of a front view of a multi-zone illuminator in accordance with the present invention;

Figure 5 is a schematic diagram of a bottom view of a multi-zone illuminator according to the present invention;

Figure 6 is schematic diagram of a side view of a multi-zone illuminator according to the present invention;

Figure 7a-d are a schematic diagram of the power distribution system according to the present invention;

Figure 8 is a block diagram showing the operation of the light interference elimination circuit (LIEC) in accordance with the present invention.

Corresponding numerals and symbols in the different figures refer to corresponding parts unless otherwise indicated.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The continuing down scaling of device dimensions in VLSI/ULSI circuits places increasingly challenging demands on the manufacturing tools and technologies required to manufacture complex microelectronic devices. Rapid technology advancements have reduced the minimum feature sizes of digital integrated circuits into the submicron regime. As a result, short-time and or activated low temperature

processes are considered to be essential for minimizing the dopant distribution problems, increasing the device fabrication yield, and achieving enhanced process control during the device fabrication sequence.

RTP operates based on the single-wafer processing methodology which is considered desirable for flexible fast turn-around integrated circuit manufacturing.

Figure 1 is a schematic representation of a semiconductor processing reactor 100 that establishes the environment of the present invention. Within a single-wafer RTP reactor 100 such as the Texas Instruments' advanced automated vacuum processor (AVP), may reside semiconductor wafer 60. Beginning at the bottom right-hand corner of Figure 1, gas distribution network 102 may comprise two gas manifolds: a non-plasma process gas manifold and a plasma manifold. The non-plasma gas manifold penetrates through reactor wall 108 via gas line 104 and process chamber wall 110 to proceed through ground electrode 112 and into gas injector 114. The plasma manifold connects into discharge cavity 118 via gas line 106 for generating process plasma. The process plasma activated species pass within plasma discharge tube 120 through reactor casing 108 and process chamber wall 110, through ground electrode 112 and into plasma injector 122 near nonplasma gas injector assembly 114. Above gas injector assembly 114 and supported by low thermal mass pins 124 appears semiconductor wafer 60. The low thermal mass pins 124 are supported by ground electrode 112 (or a liner, not shown) within process chamber 126. Wafer processing may be conducted with only thermal activation or with a combination of thermal and plasma process activation.

Process chamber 126 includes optical quartz window 128 which separates semiconductor wafer 60 from a multi-zone illuminator 130 of the present invention. In association with the multi-zone illuminator 130 may be multi-point temperature sensor 132 (not shown) as described in U.S. Patent Application Serial No. 702,646 by M. Moslehi, et al. filed on April 24, 1991 and assigned to Texas Instruments Incorporated. Vacuum pump connection 134 removes flowing process gas and plasma from process chamber 126 and into pumping package 136. Additionally, isolation gate 138 permits passage of semiconductor wafer 60 from vacuum load-lock chamber 140 into RTP process chamber 126. To permit movement of semiconductor wafer 60 into process chamber 126, chamber collar lift mechanism 142 supports process chamber collar 110.

Within vacuum load-lock chamber 140 appears cassette 144 of semiconductor wafers 60 from which wafer handling robot 146 removes a single semiconductor wafer 60 for processing. To maintain load-lock chamber 140 under vacuum, load-lock chamber 140 also includes vacuum pump connection 148.

Process control computer 150 controls the processing of semiconductor wafer 60 in RTP reactor 100. Control signals from process control computer 150 include signals to multi-zone controller 152. Controller (or multi-zone controller) 152 provides various signals to multi-zone lamp module power supply 154. Illuminator power supply 154 responsively provides power settings to multi-zone illuminator 130.

Process control computer 150 also directs pressure set points to pumping package 136 as well as gas and plasma inlet flow signals to mass-flow controllers in the gas distribution network 102. To provide proper activation of plasma species at discharge cavity 118, process control computer 150 provides a control signal to microwave source 156 which, in the preferred embodiment, operates at a frequency of 2450 MHZ.

Process control computer 150 checks the status of multi-zone illuminator 130 via line 158 for diagnosis/prognosis purposes and provides multiple temperature control signals to multi-zone controller 152 in response to temperature readings of multi-point sensors (not shown). The multi-zone controller receives measured multi-point temperature sensor outputs (not shown) as well as the desired wafer temperature setpoint (from computer) and delivers power setpoints to the lamp zone power supplies. Sensing lines 159 between process control computer 150 and multi-zone illuminator 130 of the present invention include signals from multi-point temperature sensor (not shown) for real-time semiconductor wafer 60 temperature measurements as well as the status of the zone lamps to monitor aging and failure of the lamps.

Figure 2 shows a perspective view of the Texas Instruments AVP or advanced/automated vacuum processor operating as an RTP reactor 100 for purposes of the present invention. Process chamber 126 is mounted on reactor frame 136. Process chamber 126 rigidly supports multi-zone illuminator 130. Adjacent to process chamber 126 is vacuum load-lock chamber 140 within which appears cassette 160 for holding semiconductor wafers 144. Adjacent to vacuum load-lock chamber 140 is process control computer 150 which controls the operation of the various elements associated processing reactor 100.

Figure 3 shows a schematic view of the main components of a multi-zone illuminator 130 of this invention (components shown separate from each other). The main components include a water-cooled lamp housing/reflector 200, an array of multi-zone heating lamps 328, a lamp socket base plate 322, and a power wiring module 320. The power wiring module 320 provides electrical connections between the lamp zones and external electrical power supplies (not shown). The base plate 322 holds all the lamp sockets. The multi-zone heating lamps 328 penetrate through the water-cooled lamp tubes 329 within the

water-cooled lamp housing/(reflector assembly 200. Additional water-cooled tubes 326 with a smaller diameter are included for insertion of a multi-point temperature sensor system for multi-zone lamp and temperature control. These sensors are inserted into the multi-zone illuminator assembly 130 through various holes 325, 324, 210, which are aligned between the power wiring module 320, lamp base plate 322, and water-cooled lamp housing/reflector 200.

The preferred embodiment of the invention is shown in more detail in Figure 4. The multi-zone illuminator 130 consists of a lamp housing 200 which has a series of open spaces or tubes through which an array of heating lamps 220 and dummy lamps 222 protrude. Dummy lamps 222 are shown in the periphery of housing 200 but they may be located elsewhere. On the bottom of housing 200 is a gold-plated reflector plate 230. Lamp housing 200 is water-cooled to prevent heating of the reflector 230 and the pyrometer light pipes 210. Referring to Figure 5, the lamps 220 are arranged vertically as point sources along the axis of the illuminator, distributed over several concentric rings. The preferred embodiment uses four concentric rings, wherein each ring forms one heating zone. The number of rings (or zones) may be more or less than four. Zone 1 consists of 5 heating lamps 240 and a peripheral dummy lamp 242 located on the periphery of housing 200. Zone 2 consists of 11 heating lamps 250 and a dummy lamp 252 located on the periphery of housing 200. Zone 3 consists of 20 lamps 260 and four dummy lamps 262, 264, 266, and 268 located on the periphery of housing 200. Zone 4 consists of 29 lamps 270 and a dummy lamp 272 located on the periphery of housing 200. In the preferred embodiment lamps 220 are each 1 KW tungsten-halogen lamps. However, it should be noted that lamp ratings of 500 watts, 750 watts, 2 kw or even more may also be used. Other types of lamps different from the tungsten-halogen type may also be used.

Referring to Figure 4, housing 200 is located above and separate from wafer 60 by optical window 290. Optical window 290 may be made of quartz or another transparent material. On the peripheral bottom edge of optical window 290 is a reflective film coating 295. The reflective film 295 may be of, for example chromium and may be used to prevent direct exposure of the vacuum O-ring seals to lamp light. The distance between reflector plate 230 and wafer 60 and the distance between heating lamps 220 and wafer 60 is adjusted by adjustable elevator 300 and an adaptor ring placed between the lamp housing 200 and the quartz window 290. Motor 350 drives lead screw 330 which itself drives (raises or lowers) nut 370. Nut 370 is connected to carriage 202. Carriage 202 is connected to wiring module 320 and lamp support. This mechanism raises or lowers the lamp array with respect to the main lamp housing 200 (reflector 230). A separate mechanism (not shown) is provided to adjust the spacing between the lamp reflector 230 and the quartz window 290. The elevator mechanism 300 can be used for two purposes: (i) to adjust the relative spacing between the lamp array and the quartz window 290 (with a given reflector-to-quartz spacing); and (ii) to raise the entire lamp array and associated wiring module 320 out of the main lamp housing 200 (water-cooled reflector 230). The latter will allow rotating the lamp array in order to replace lamps. As a result, the overall optical flux of the illuminator and its distribution pattern can be optimized for a wide range of process parameters, including chamber pressure and total gas flow rate. Figure 4 shows lamp housing 200 at a typical position near optical window 290. Figure 6, shows illuminator 130 from a side view, indicating the radial positions of various lamps in four concentric zones, as well as the pivot for rotation of the illuminator assembly for maintenance.

Power supplies 340 through 370 are three phase power supplies. Referring to Figure 7, Zone 1 is powered by power supply 340. Lamps 240 may be connected as follows: Lamps 240a and 240b connected in series between phase 1 and phase 2, lamps 240c and 240d connected in series between phase 2 and phase 3, lamp 240e and dummy lamp 242 connected in series between phase 1 and phase 3.

Referring to Figure 7, zone 2 is powered by power supply 350. Between phases 1 and 2 lamps 250a and 250b are connected in series, and lamps 250c and 250d are connected in series. Between phases 2 and 3 lamps 250e and 250f are connected in series and lamps 250g and 250h are connected in series. Between phases 1 and 3 lamps 250i and 250j are connected in series, and lamp 250k and dummy lamp 252 are connected in series.

Referring to Figure 7, zone 3 is powered by power supply 360. Between phases 1 and 2 the following pairs of lamps may be connected in series: 260a and 260b, 260c and 260d, 260e and 260f, 260g and dummy lamp 262. Between phases 2 and 3 the following pairs of lamps may be connected in series: 260h and 260l, 260j and 260k, 2601 and 260m, 260n and dummy lamp 264.Between phases 1 and 3 the following pairs of lamps may be connected in series: 260o and 260p, 260q and 260r, 260s and dummy lamp 266, 260t and dummy lamp 268.

Referring to Figure 7, zone 4 is powered by power supply 370. Between phases 1 and 2 the following pairs of lamps may be connected in series: 270a and 270b, 270c and 270d, 270e and 270f, 270g and 270h, 270l and dummy lamp 272. Between phases 2 and 3 the following pairs of lamps may be connected in series: 270j and 270k, 270l and 270m, 270n and 270o, 270p and 270q, 270r and 270s. Between phases 1 and 3 the following pairs of lamps may be connected in series: 270t and 270u, 270v and 270w, 270x and 270y, 270z and 270aa, 270ab and 270ac. The above described connection is an example only. As will be

apparent to those skilled in the art, other combinations are possible (depending on the power supply and lamp voltage ratings).

Lamps 220 may, for example, be tungsten-halogen or plasma arc lamps and are used to heat the semiconductor wafer 60 during processing. The concentric rings of lamps 220 in the preferred embodiment provide as much as 58 kw of power for RTP. Because of the multiple lamp sources in each zone and their proximity to one another, each zone provides a continuous photon radiation ring at the surface of wafer 200 and results in uniform wafer heating. Using multiple independent point source lamps in a zone and connecting them to one power supply is significantly less complicated and more economical and practical than providing a single ring shaped lamp.

Dummy lamps 222 are identical to lamps 220 except that they are placed in housing 200 such that their output radiation is isolated from the wafer 60. The isolation is accomplished by blocking the end sections of the dummy light pipes with a cap 224 as shown in Figure 4. The purpose of dummy lamps 242, 252, 262, 264, 266, 268, and 272 is to measure the light modulation depth as is described below, for the purpose of precise pyrometry-based temperature measurement.

Multi-point temperature sensors, such as those described in U.S. Patent Application Serial No. 702,646 filed April 24, 1991, can be used to perform real-time temperature measurement and uniformity control during transient and steady-state thermal cycles. However, lamps producing radiance with infrared wavelengths of less than 3.5 microns are desired because the quartz window 290 is transparent at those wavelengths. At wavelengths of less than 3.5 microns, pyrometry measurements are, however, subject to lamp interference effects which can cause significant temperature measurement errors and process repeatability problems. Thus, a light interference elimination circuit (LIEC) is desired.

Each dummy lamp includes a light interference elimnator circuit (LIEC) pyrometer insert light pipe 205 for LIEC modulation depth measurement and control for their respective zones. Dummy light pyrometers 206 (shown in Figure 8) associated with light pipes 205 measure the radiation from the dummy lamps 222. Multiple pyrometer insert light pipes 210 are also embedded in housing 200 for up to 5 or more radial wafer temperature measurements. Wafer pyrometers 211 associated with light pipes 210 measure radiation from both the lamps 220 (due to their interference) and wafer 60. A power modulation source (not shown) is provided for modulating the electrical power source to a selected modulation depth such that the output radiation of the dummy lamps 222 varies with the selected AC modulation but the temperature of the wafer 60 remains substantially constant. Circuitry is provided for determining the fraction of total radiation collected by pyrometers associated with light pipes 210 which is emitted by the wafer heating lamps 220 and calculating the true temperature of wafer 60. Referring now to figure 8, a sample or portion of the spectral power of the lamp radiation is measured by a dummy lamp pyrometer 206. The spectral power includes an AC component ΔI (for reference, ΔI is the peak-to-peak AC signal) and the DC component I. The dummy lamp pyrometers 206 operate in the same spectral band $\Delta\lambda$, and therefore the same center wavelength, as the wafer pyrometers. As an example, λ_o may be 3.3 μm and $\Delta\lambda$ may be 0.4 μm.

A lamp pyrometer output signal is provided to a low-pass filter 428 which outputs the DC component I. The dummy lamp pyrometer 206 output is also provided to a high-pass filter 430 and a peak-to-peak to DC converter 432 which in turn outputs the AC portion of the lamp intensity ΔI. (Note: If desired, both blocks 430 and 432 can be bypassed without affecting the functionality of LIEC).

The lamp radiation modulation depth M_L is determined by dividing the peak-to-peak value of the AC component ΔI of the dummy lamp pyrometer 206 by its DC component I in divider 434.

At the same time, the AC component $\Delta I'$ of a wafer pyrometer 211 is determined from high-pass filter 436 and peak-to-peak to DC converter 438. The AC component $\Delta I'$ of the wafer pyrometer 211 is then divided by the measured lamp modulation depth M_L in dividing circuit 440. The output Y_2 of the divider is the amount of DC lamp interference, i.e., the main source of measurement error in the wafer temperature sensor or wafer pyrometer 211. Again, blocks 436 and 438 are eliminated/bypassed if blocks 430 and 432 are eliminated/bypassed.

The lamp interference effect or Y_2 may be subtracted from the DC component I' from the wafer pyrometer 211 (obtained from low-pass filter 442) in difference or differential amplifier circuity 444. The output Y_3 of the difference circuit 444 is based on the true wafer temperature and substantially all lamp interference portion has been eliminated.

This technique also provides real-time data on spectral wafer reflectance (or emissivity) in the spectral band of the pyrometer. This information can be used for real-time correction/compensation of wafer temperature measurement using pyrometry. The spectral reflectance is essentially proportional to the ratio of the AC signal level $\Delta I'$ detected by the wafer pyrometer 211 to the AC signal level ΔI detected by the dummy lamp pyrometer 206. The emissivity is proportional to the output of divider 452, labeled as Y_4 in Figure 5. Y_4 is a measure of the wafer spectral emissivity at the same center wavelength as the pyrometers. A more detailed description of the operation of a LIEC (without embedded dummy lamps) is described in co-pending patent application serial no. 785,386, filed October 30, 1991 and assigned to

Texas Instruments, Inc and is hereby incorporated by reference.

A few preferred embodiments have been described in detail hereinabove. It is to be understood that the scope of the invention also comprehends embodiments different from those described, yet within the scope of the claims.

While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments, as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to the description. It is therefore intended that the appended claims encompass any such modifications or embodiments.

Claims

1. A multi-zone illuminator for processing semiconductor wafers comprising:

   a plurality of source lamps arranged in a plurality of zones for generating optical energy for illuminating the wafer;

   optical means arranged to directing the optical energy from the source lamps to the wafer; and

   a light interference elimination means including at least one dummy lamp associated with each zone of source lamps for measuring light modulation depth.

2. The illuminator of claim 1, further comprising a lamp housing capable of supporting the source lamps embedded in a bottom surface thereof, wherein the source lamps are arranged in a plurality of concentric circular zones and the optical means comprise a reflector attached to said bottom surface.

3. The illuminator of claim 1 or claim 2, further comprising:

   a plurality of light pipes associated with the zones of source lamps and a light pipe located in each of said dummy lamps for measuring the temperature of the wafer.

4. The illuminator of claim 3, wherein said light interference elimination means comprises:

   a plurality of wafer temperature sensors insertable in said plurality of light pipes which pipes are embedded in the bottom surface of the housing;

   a plurality of lamp radiance sensors insertable in said light pipes located in said dummy lamps;

   a modulation source for modulating said source lamps and dummy lamps to a selected modulation depth and frequency;

   circuitry to determine the magnitude of the modulation depth of the radiation detected in at least one of said plurality of lamp radiance sensors;

   circuitry to determine the magnitude of the lamp interference signals embedded in said plurality of wafer temperature sensors; and

   circuitry to subtract said lamp interference signals from said wafer temperature sensor signals to determine the wafer temperature.

5. The illuminator of any preceding claim, wherein said source lamps are associated within each of said zones to provide an approximately continuous ring of said optical energy from each of said zones at the semiconductor wafer surface.

6. The illuminator of any preceding claim, wherein said illuminator further comprises a plurality of cooling channels for flowing a cooling fluid to cool said reflector.

7. The illuminator of any preceding claim, further comprising a plurality of adjustable power supplies, each of said adjustable power supplies associated to provide electrical power to a respective lamp zone.

8. The illuminator of claim 7, wherein each power supply also provides power to at least one dummy lamp.

9. The illuminator of any preceding claim, wherein said source lamps comprise tungsten-halogen lamps.

10. The illuminator of any preceding claim, further including a means for adjusting the spacing between said lamps and said wafer wherein said means for adjusting is also capable of adjusting the spacing between said optical means and said wafer, and wherein the spacing between the lamps and the wafer may be adjusted independently of the spacing between the optical means and the wafer.

11. The apparatus of any preceding claim, wherein said optical means is a flat gold plated reflector.

12. The illuminator of any preceding claim, wherein said lamp zones include four concentric lamp zones comprising an outer circular lamp zone having 29 point-source lamps, an outer middle circular lamp zone having 20 point-source lamps, an inner middle circular zone having 11 point-source lamps, and a center circular zone having

five point-source lamps.

13. A rapid thermal processor adapted to process a semiconductor wafer, said processor comprising:

a quartz window above said wafer; and

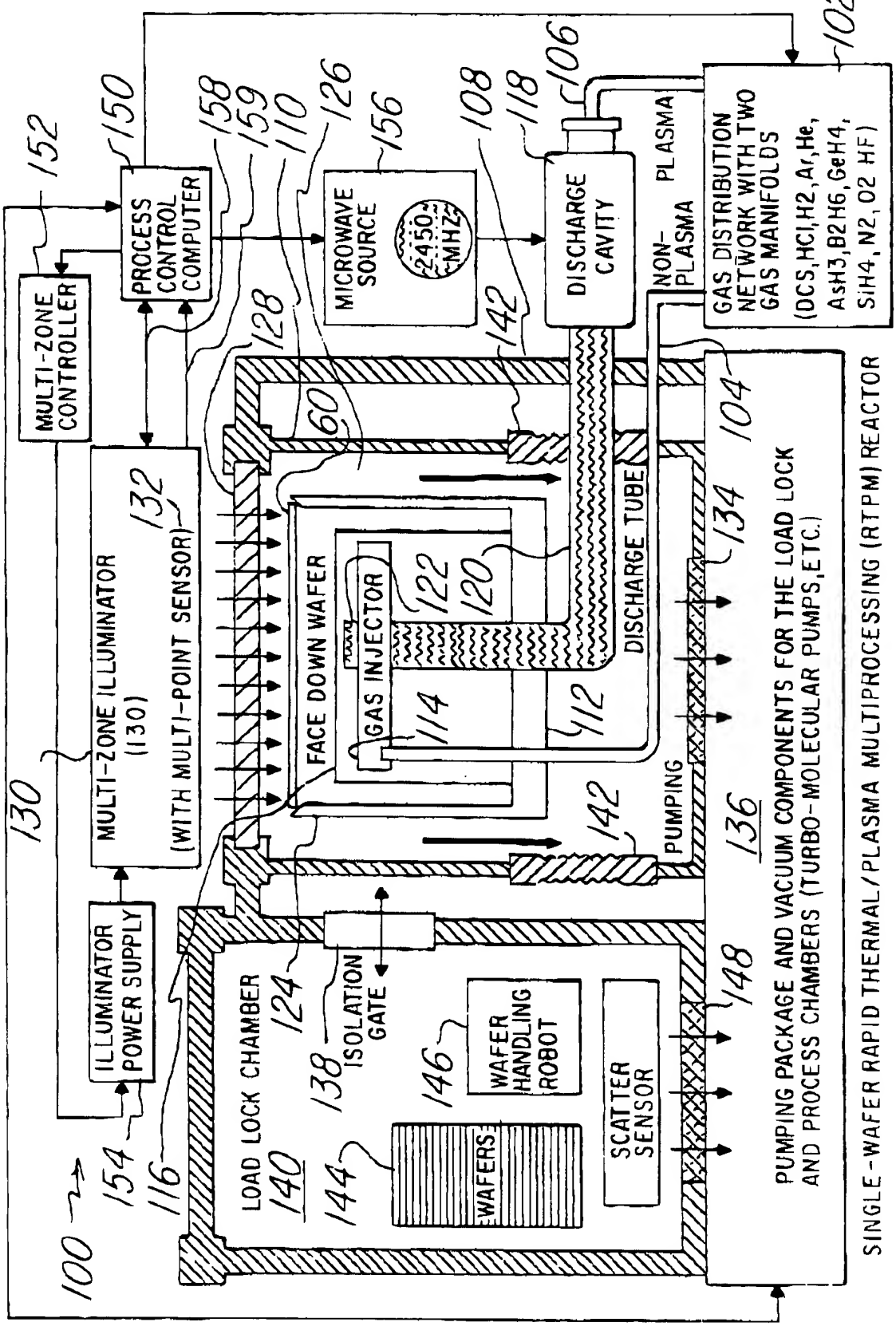
a multi-zone illuminator according to any of claims 1 to 12 and located above said quartz window.

14. A method of illuminating a semiconductor wafer in processing comprising:

providing a plurality of source lamps arranged in zones to generate optical energy for illuminating the wafer;

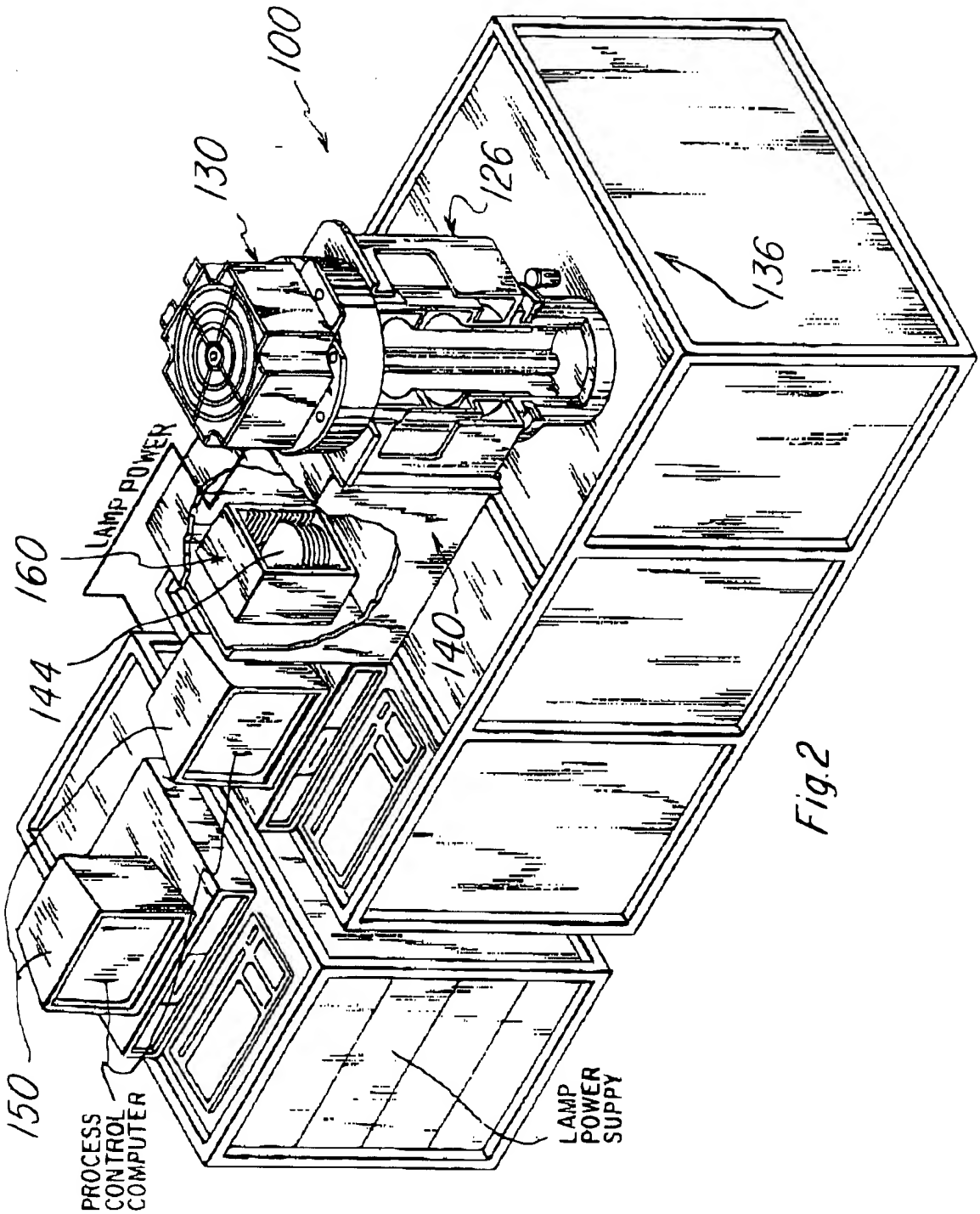
directing said optical energy with optical means from the source lamps to the wafer; and

measuring light modulation depth of the optical energy with light interference elemination means which includes at least one dummy lamp to control said illumination.



SINGLE-WAFER RAPID THERMAL/PLASMA MULTIPROCESSING (RTPM) REACTOR

Fig. 1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160
144
140
150
PROCESS CONTROL COMPUTER
LAMP POWER SUPPY

Fig.2

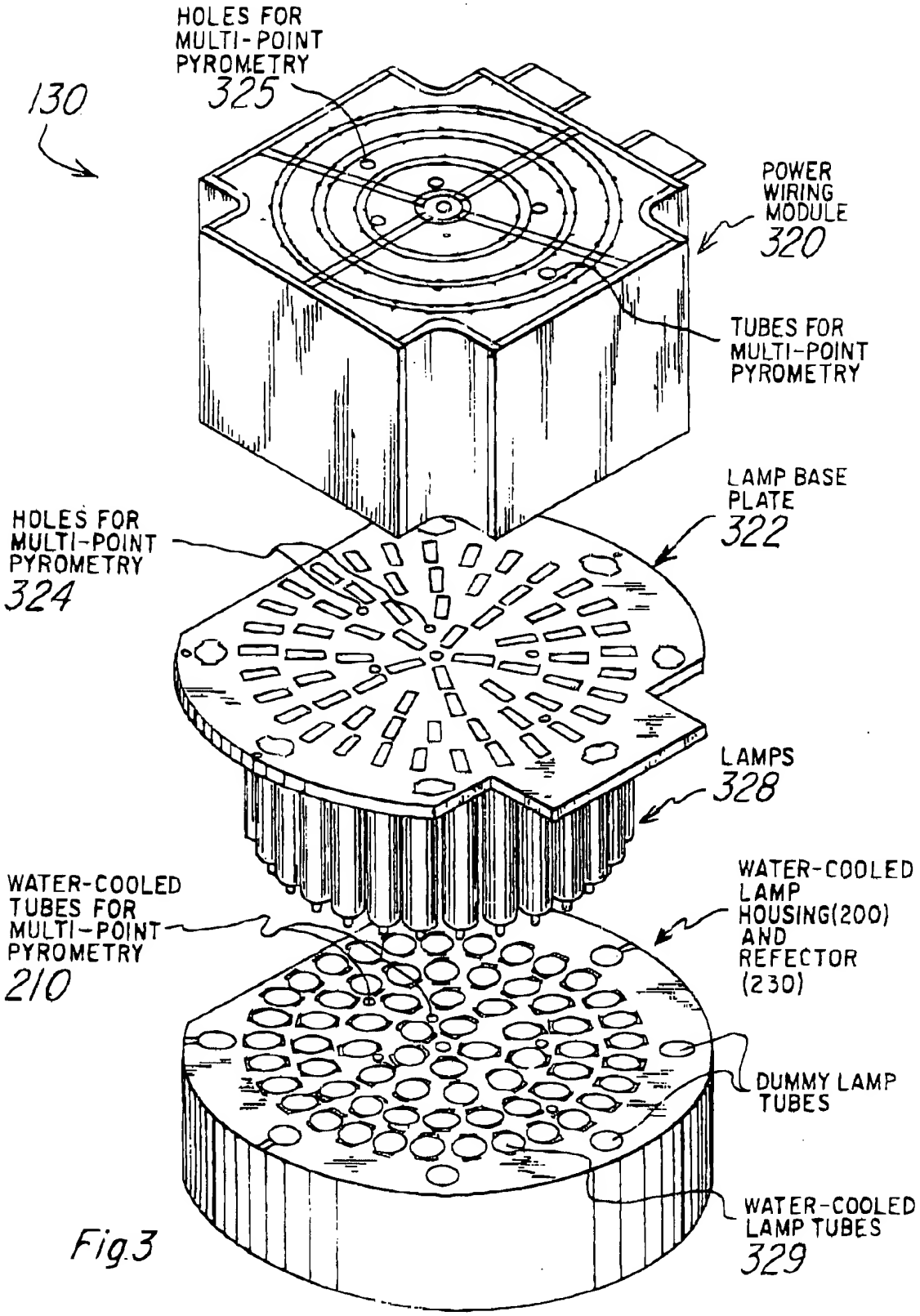
130
HOLES FOR MULTI-POINT PYROMETRY 325
POWER WIRING MODULE 320
TUBES FOR MULTI-POINT PYROMETRY
LAMP BASE PLATE 322
HOLES FOR MULTI-POINT PYROMETRY 324
LAMPS 328
WATER-COOLED TUBES FOR MULTI-POINT PYROMETRY 210
WATER-COOLED LAMP HOUSING(200) AND REFECTOR (230)
DUMMY LAMP TUBES
WATER-COOLED LAMP TUBES 329

Fig.3

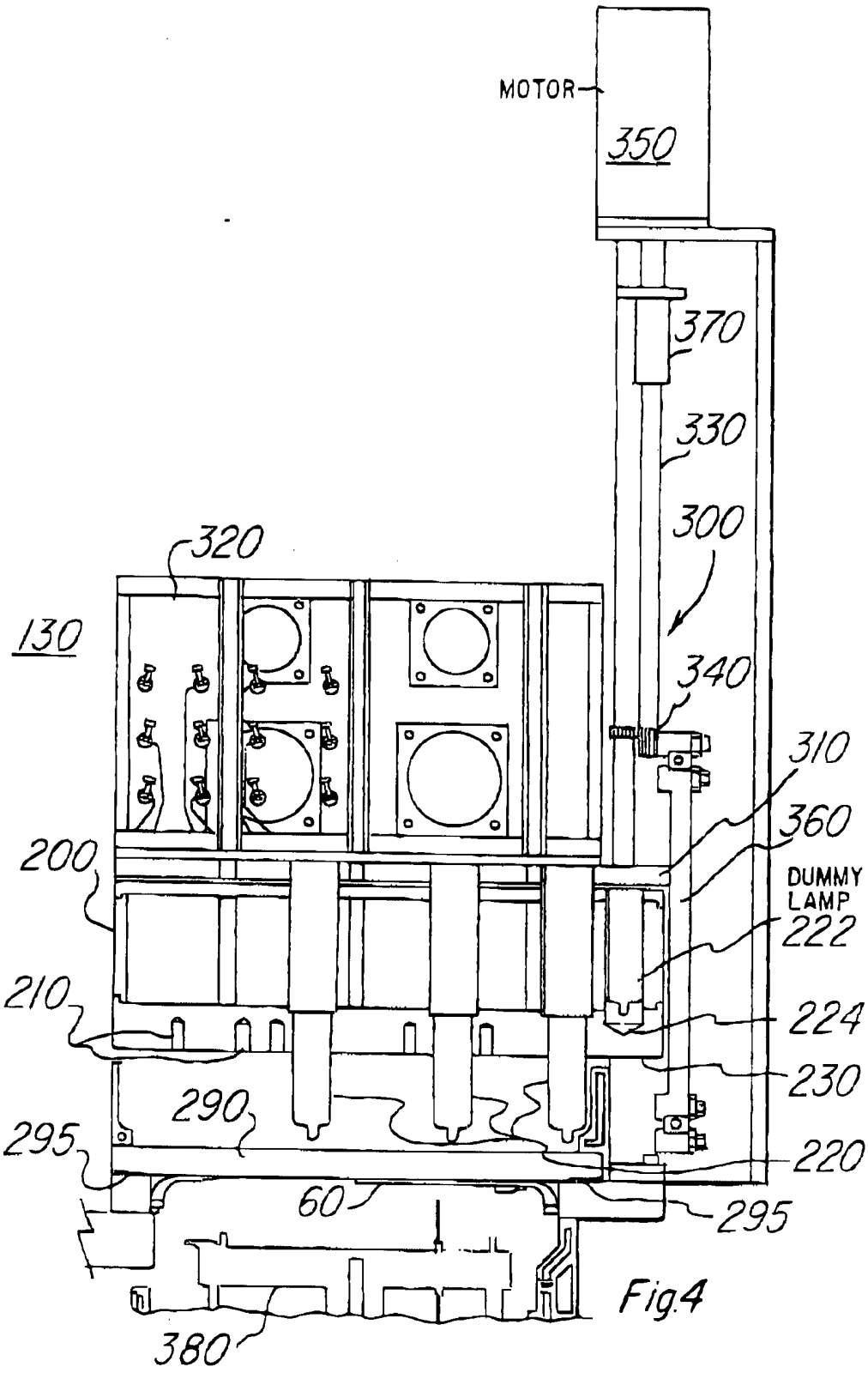
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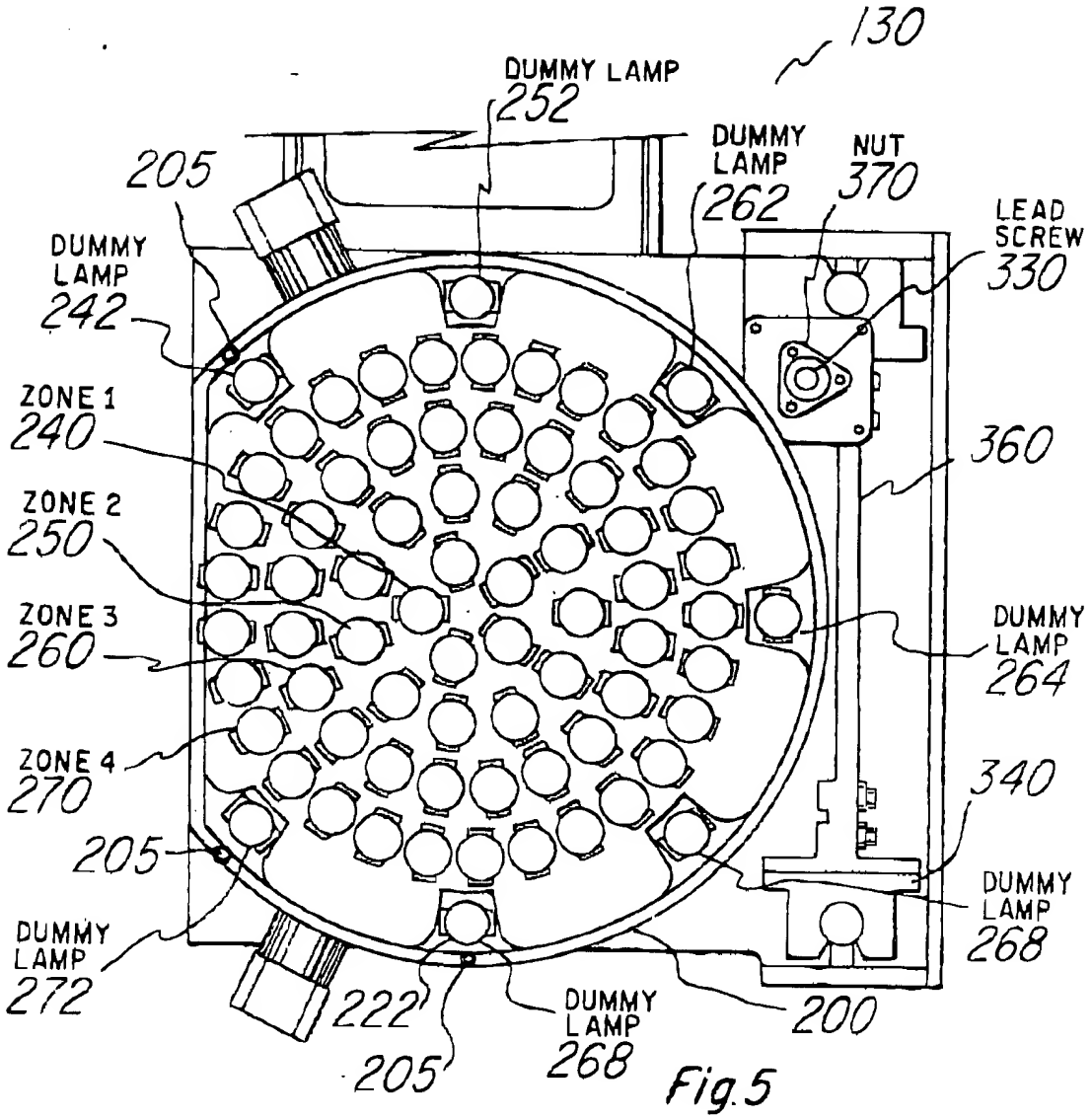
Fig.4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264
ZONE 4
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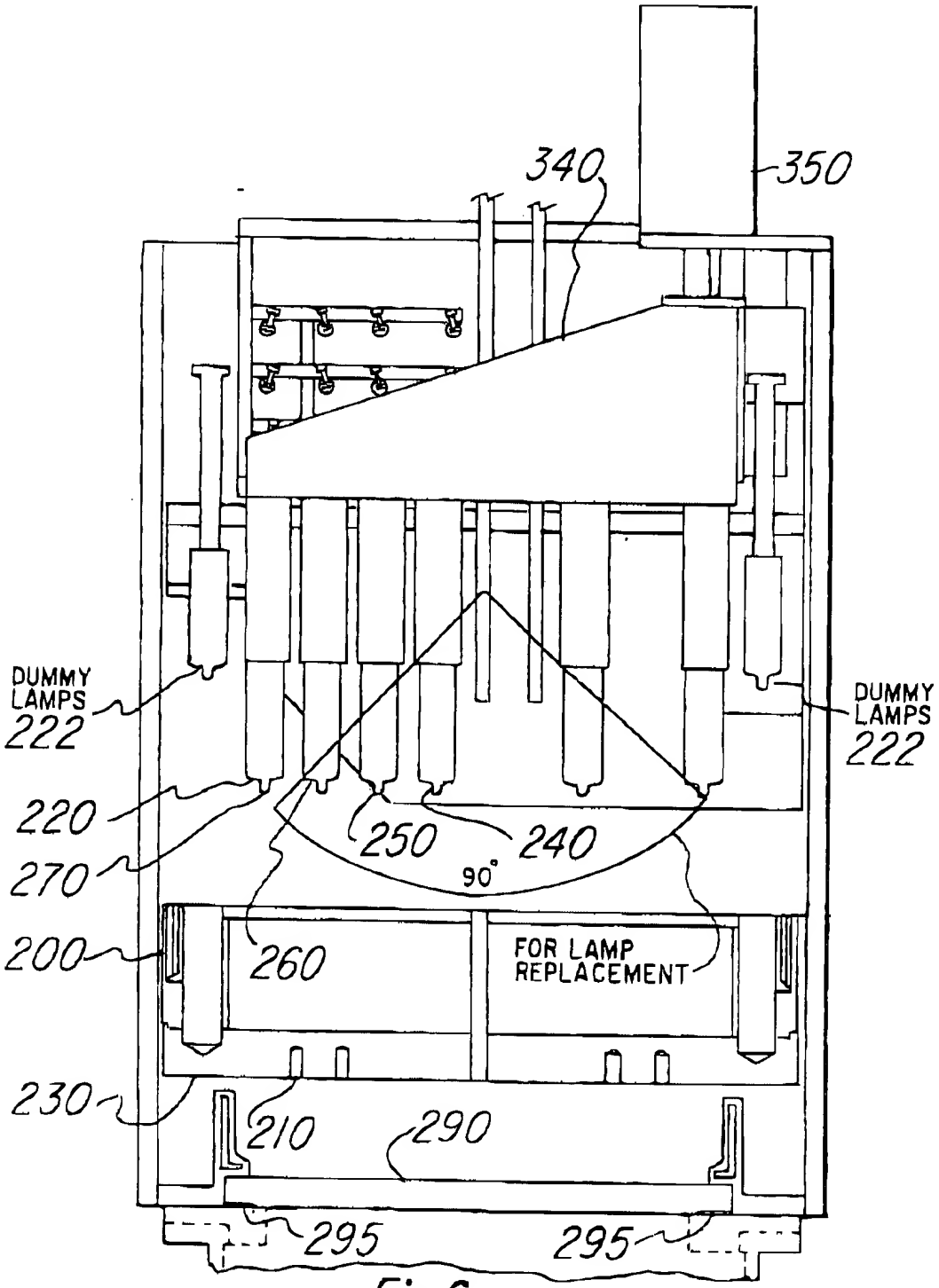
LAMP
268

Fig.5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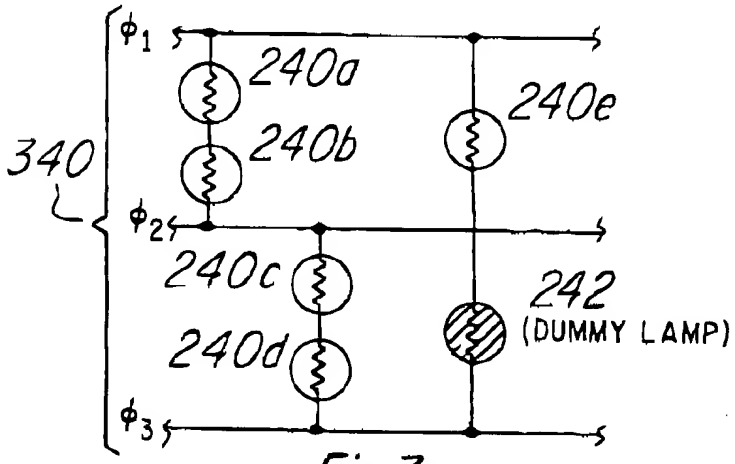
290
295
295

Fig.6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ϕ_2
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ϕ_3

Fig. 7a

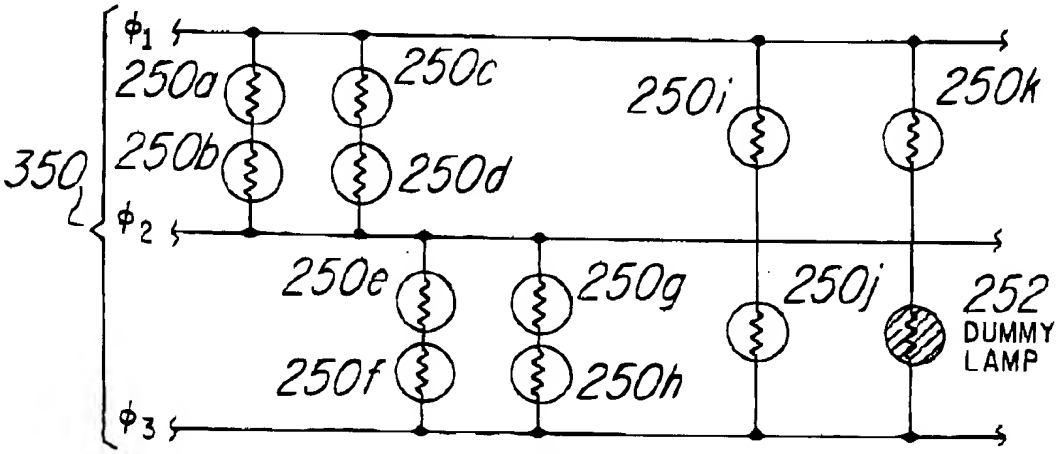
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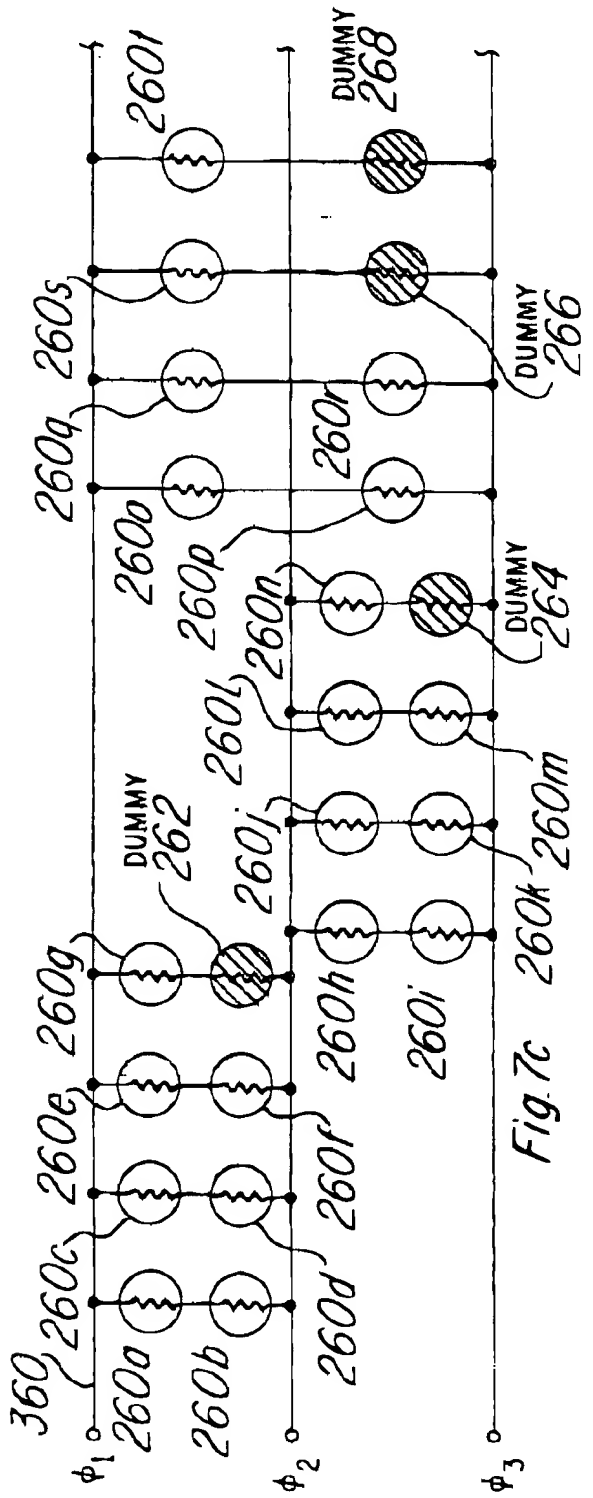
Fig. 7b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DUMMY 264
DUMMY 266
DUMMY 268
ϕ_1
ϕ_2
ϕ_3

Fig. 7c

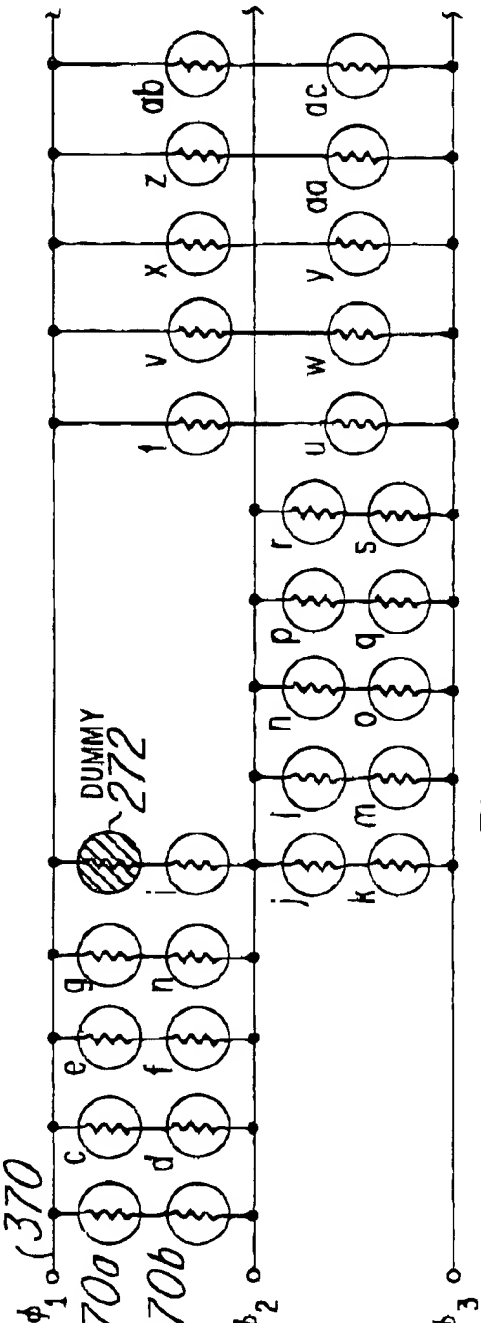
370
270a
270b
DUMMY 272
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t
u
v
w
x
y
z
aa
ab
ac
ϕ_1
ϕ_2
ϕ_3

Fig. 7d

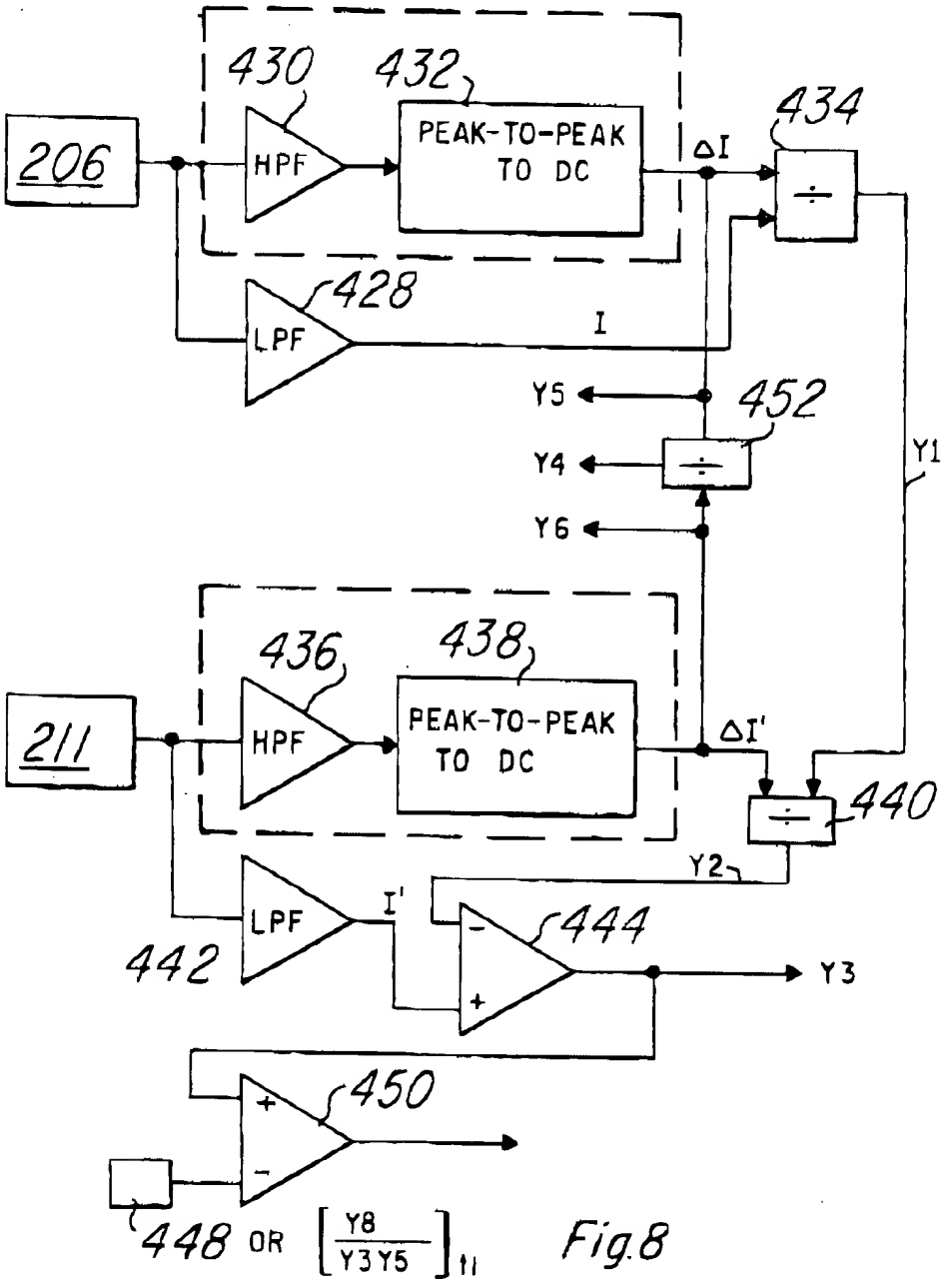
206
430
HPF
432
PEAK-TO-PEAK TO DC
ΔI
434
428
LPF
I
Y5
452
Y4
Y6
Y1
211
436
HPF
438
PEAK-TO-PEAK TO DC
ΔI'
440
Y2
LPF
I'
442
444
Y3
450
448 OR [Y8/Y3Y5]11

Fig.8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 10 5404

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 468 874 (SUMITOMO ELECTRIC INDUSTRIES LTD.) * column 2, line 27 - column 3, line 47; figures 3A,3B *	1,2,5,7, 14	H01L21/00
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 190 (E-517)18 June 1987 & JP-A-62 020 308 (HITACHI LTD) * abstract *	1,7	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H01L
G01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 AUGUST 1993	BOLDER G.

CATEGORY OF CITED DOCUMENTS

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